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BIBLIOGRAPHIC SURVEY OF QUANTITATIVE APPROACHES TO MANPOWER PLANNING

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WP 833-76 January 1976

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A B S T R A C T

A bibliographic survey of quantitative methods for national industry/regional and particularly corporate manpower planning is presented. After a brief review of issues and techniques at the first two levels, quantitative approaches to corporate manpower planning are examined: static and dynamic flow models, assignment models, and elements of manpower information systems. Trends and issues facing corporate manpower planning are considered. The paper concludes with pointers to additional bibliographies.

ACKNOWLEDGMENTS

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1.0 INTRODUCTION

Manpower planning is truly an interdisciplinary activity rooted in such diverse fields as economics, psychology, law and public administration, industrial relations, computer science, and operations research. Considering that most of the parental disciplines are themselves in a tremendous state of flux, it should come as no surprise to find manpower planning in a similar state, or more so. Judging by the vast body of literature alone, it seems fair to say that during the last quarter century manpower planning has started to emerge as a field in itself.

Although bibliographic reviews exist, their orientation is largely towards the social sciences which have shown a great deal of interest in this area. In recent years, however, an effort has been underway to put manpower planning on a more quantitative footing. The purpose of this paper is to attempt a bibliographic survey of quantitative techniques and models in manpower planning - particulary at the corporate level.

This paper is unabashedly patterned on the earlier annotated bibliography by Lewis (114) in the UK although its bias is towards the North American continent. To give the reader a more comprehensive understanding of the scope of the field, the survey starts with an overview of manpower planning at the national and industry/regional levels before focusing on the corporate level.

For those knowledgeable in the field, the summary contains pointers to additional bibliographies as well as basic reference material for the recent initiate.

2.0 NATIONAL MANPOWER PLANNING

National manpower planning is the integral portion of macro-economic planning which attempts to achieve maximum utilization of human resources in terms of societal goals.

The formulation and expression of national goals and priorities is one of the key areas of interest and responsibility of the political system within a country. Although a common theme runs through the national aspirations of all countries it goes without saying that they diverge on many issues. In the USA, for example, the President's Commission on National Goals[1] issued the following list (103) with its attendant implications for manpower needs (104): improved living standard, capital expansion with emphasis on transportation and utilities, urban development, social welfare, health coverage, education, transportation, national defense, research and development increases, international aid, space exploration, agriculture, manpower retraining, area redevelopment to promote full employment in regionally depressed regions, and development of natural resources.

The harnessing of the economy to attain desired aims requires an understanding of the operation of the capitalistic system which is presented in the simplified three sector closed economy of Fig. 1. The

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[1] See (15) for a discussion on social indicators and their measurement.

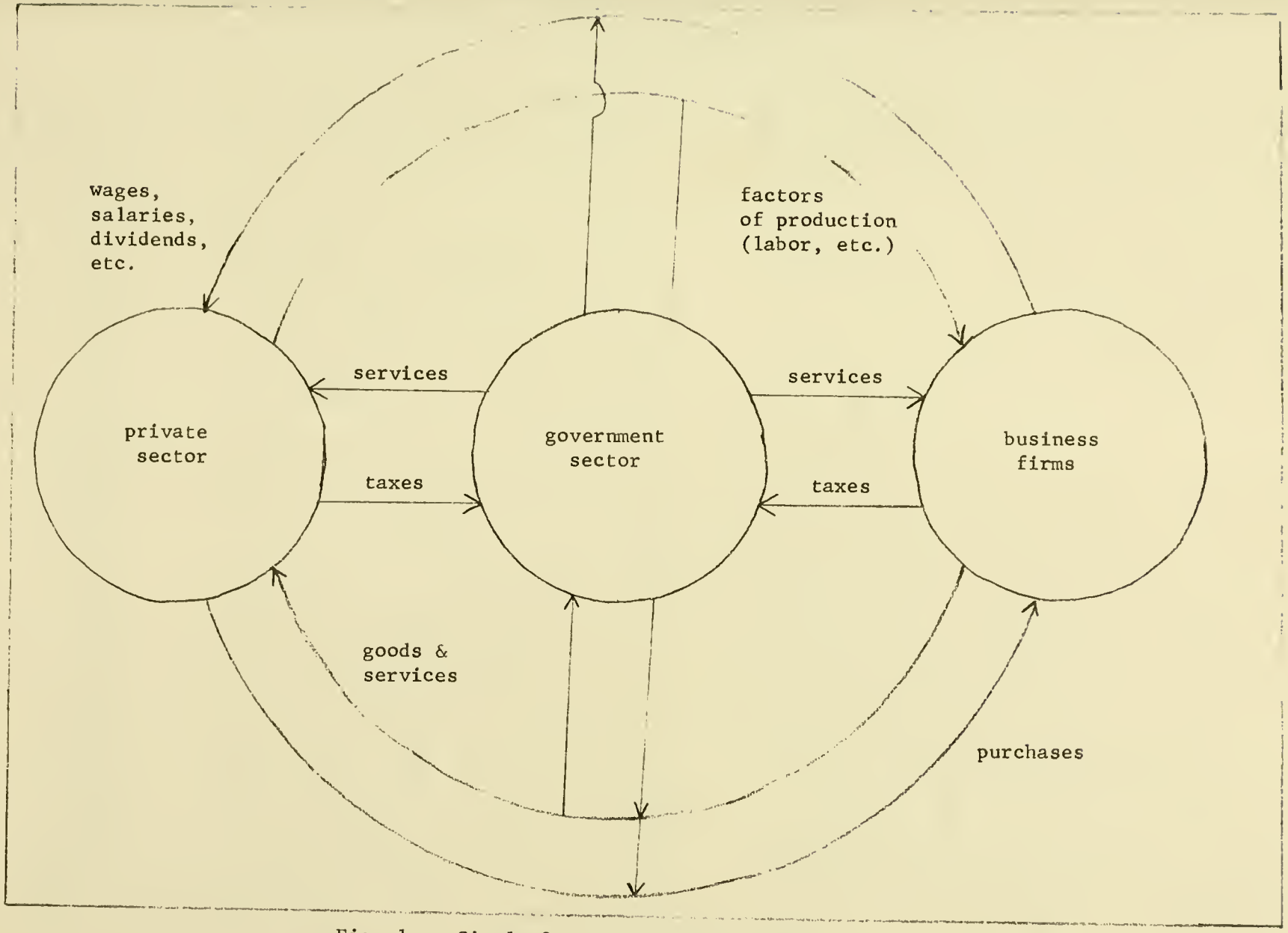

Fig. 1: Simple 3-Sector Economic Model

interdependence of manpower planning and economics is illustrated in a four sector economy of ref.109which highlights three vertical feedback loops considered in manpower economics: domestic output places pressure on future demands of capital (k) and labour (l) for a given rate of technological progress[2] (r); industrial participation and mobility affect wage and price levels; lack or obsolescence of skills necessitates determination of education and training requirements funded by government expenditures. Of particular importance to the manpower planner are the demographic accounting variables constituting the whole population (employed, unemployed, households, persons undergoing education and training) as well as data on skill requirement, industrial mobility, and productivity which form the basis of manpower statistics.

Manpower planning is historically rooted in the gathering of manpower statistics dating from the times of the Roman census to the accounting of slaves, and eventually to population censuses towards the end of the eighteenth century (140). Thomas Matthews and Adolphe Quételet were early contributors to the establishment of labor economics as an autonomous field in the following century. Indeed, Quételet's emphasis on quantitative manpower analysis tends to qualify him as a founding father of manpower planning. In this century, the U.K. emerged as one of the chief proponents of effective manpower statistics and continues as such today (235). In North America, the burgeoning interest in this

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[2] This is often expressed by the modified Cobb-Doublas function: $Y = Ae^{rt} K L^{B}$, where A is a constant, t is time, and B are elasticities of capital and labor respectively, and r is the rate of technological growth.

field started to blossom after WW II (140, 148). The landmark passage of the Employment Act in 1946 committing the nation to a policy of full employment tacitly legitimized manpower planning in the USA. Unfortunately, an interlude of 15 years was to transpire before the lofty ideals therein enunciated were to be recast into an "active" manpower policy through various programs. Although somewhat of a latecomer to the field, the importance of manpower planning and labor market information was definitely established with the close of the 50s. Under the initial modest aim of an "appraisal of employment and unemployment statistics", the Gordon Report (140), issued in 1962, expanded into a comprehensive stocktaking of manpower forecasts resulting in a reorientation of philosophy from data collection to data utilization. In brief, the 50s were a time of organization, the 60s experimented with diverse approaches, and the 70s are a period of consolidation and integration of the lessons learned (90, 112, 183).

Despite the tremendous impetus given by the Gordon Report the methodology of manpower forecasting is far from concrete - even the divisions of responsibilities between the public and private sectors is undecided (218). The methodology focuses on the determination of "needs" and "availability" - demand and supply within a suitably defined demographic framework (2, 109). The projection of manpower needs entails development of occupational structure models incorporating multitudinous factors relating to capital, technology, labor market characteristics, and regional variation.[3] Needs projections provide planners with: data

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[3] The Dictionary of Occupational Titles, published by US Dept. of Labor has over 35,000 job titles. See (171) for a review of occupational analysis.

for vocational guidance, scientific and technological qualification requirements; trends in occupational growth or decline; specific forecasts in selected disciplines such as science and engineering, teachers, and doctors. A central and unanswered issue in needs analysis is the relationship between occupational demands and educational requirements. Counterbalancing needs projection are availability models containing age, sex and regional demographic projections. Reconciliation of these two facets to provide an insight into the efficacy of labor force utilization is complicated by a plethora of factors including labor market operations, regional vagaries, and labor mobility within the three dimensional space of industry, occupation, and education.

The descriptive and prescriptive models used at the national level of planning may be categorized into three general groups (2): policy conditional forecasts in which the value of the dependent variables are contingent on the attainment of policy-oriented independent variables; onlooker forecasts which extrapolate historical trends; and optimizing forecasts which are driven by an objective function.

Morton (139) presents a concise historical summary of forecasting techniques starting from demographers' modified exponentials through to renewal theory, stochastic processes, moving averages and exponential smoothing. In recent years there has been a swing away from demographically based forecasts towards econometric (188) and input/output models

as well as Monte Carlo simulation. Moreover, recognition that long lead times in manpower development makes planning particularly vulnerable to changes in policy variables has stimulated research into "teleological" or target-related forecasting in which the study of explicitly stated achievable future goals is undertaken through futurist speculation or expert concensus in order to restrict the range of the exogenous variables.

Mehmet (129) describes and evaluates seven methods of forecasting requirements by industry and occupation:

- econometric method
- productivity method
- trend projection method
- employer's survey method
- method of forecasting specialized manpower requirements
- inter-area comparisons method
- elasticity of factor substitutions method.

Ahamad and Blaug (2) point out that manpower forecasting is still in its infancy yielding crude and often useless results. All too many models are still based on the woefully lacking fixed-coefficient approach pioneered by Parnes (149) utilizing productivity, education and participation ratios. The predominantly demand-oriented approach, the assumption that ratios are independent of technological growth, changes in industry output and education standards, and the failure to accommodate substitution effects have contributed to making the models suspect as serious undertakings.

Recapitulaing the above, planning[4] in various societies (108) is an amalgamation of economics, educational planning (82, 182) and labor market operations. As seen in ref. (90), the U.S.A. has made a strong legislative commitment to it which is further reflected in the programs of the Bureau of Labor Statistics shown in ref. (237). Although far from successful, planners are cognizant of current limitations, particularly with respect to decentralization of data to mirror local phenomena (115) and lack of comprehensive labor market information for planning and programming purposes (237). Excited by the possibilities of advanced computer technology, the latter area has been receiving considerable congressional interest of late. In the meanwhile, the area of human resource accounting (66, 234, 191, 236) is gathering momentum in the background in anticipation of its applicability to Manpower Planning.

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[4] See (122, 123, 229) for a selected bibliography on Canada and the USA and (1) for India.

3.0 INDUSTRY/REGIONAL MANPOWER PLANNING

Industry/Regional manpower planning falls in the middle ground between national and corporate planning (238) and, quite naturally, shares the problems of both. Industry-occupation statistics provide the basis for investigation which naturally lead into education and training requirements (82, 192). Indeed, educational modelling and planning has developed as a specialty in its own right (7, 97). The Ford Foundation, for example, has sponsored invited research in university administration using techniques such as Markov analysis (10), decision analysis (216), control theory (211), simulation (110), and mathematical programming with multiattributed criteria (74). Sandell and Wallace (167) report a goal programming formulation for student flow. Closely allied with educational planning is forecasting in particular professions (147) such as engineering (100), teachers (71), civil aviation (196, 226), and medical staff (214). Liebhafsky (115) provides insight into the issues of disaggregated planning at the state level. Purkiss and Richardson describe planning in the British Steel Industries (162).

Of particular interest to regional planners is the availability of comprehensive, accurate and timely labor market information. Although a point of contention in the recent past, it seems generally agreed that this is primarily a government responsibility (112), particularly at state level (194). During the latter 60s, several computerized job banks and/or matching systems were implemented (96, 140, 195, 237) by both public and private enterprises:

- GRAD (Graduate Resume Accumulation and Distribution) established by the College Placement Council for university graduate placement;
- IRIS (IBM Recruitment Information System);
- PICS (Personnel Information Communication System) designed as commercially operated clearing-house for professional, technical and administrative occupations;
- LINCS (USES Labor Inventory Communication System) demonstration job-matching project;
- NEA-SEARCH - teacher clearing-house for jobs;
- ESOPS (Employment Service On-Line Placement System) pilot project in Wisconsin for fully-integrated computer-assisted placement system.

Labor market information systems are still in their infancy, and experiencing serious growing pains, (127, 194). Nonetheless, a sense of optimism justifiably prevails (96, 140, 195, 237) as development continues.

As industry-regional manpower planning is inextricably interwoven with national and corporate manpower planning, it suffices for purposes of this paper to highlight some of the salient issues and to move on to the planning at the level of the firm.

4.0 CORPORATE MANPOWER PLANNING

4.1 General

Although it has just recently progressed past the nascent stage, corporate manpower planning (16) is the most advanced area with respect to the national and industry/regional perspectives. Signs of its maturity are evidenced by the growing consensus of what constitutes the field.

Broadly stated, manpower planning is the process to ensure that the right people are at the right place at the right time in sufficient numbers to efficiently accomplish anticipated tasks (208). Wikstrom (227) subsumes four distinct activities which largely coincide with the views of Cassell (34):

- forecasting future requirements,
- inventorying and analyzing current manpower resources,
- anticipating manpower problems by determining quantitative and qualitative discrepancies between needs and availabilities,
- planning the necessary programs of recruitment, selection, training, development, motivation and compensation so that future manpower requirements will be met.

Walker (212) compresses this into two constituents:

> "Forecasting, the determination of organizational needs and available manpower supply within the organization at various times through forecasting; and Programming, the planning of activities which will result in the recruitment of new employees for the organization, further development activities for employees, designation of replacements for key managers, and new expectations for effective top management planning."

He goes on to integrate the two basic elements in a time-frame: short-range (0-2 years), intermediate-range (2-5 years), long-range (5-10 years). Burack (28) and Doeringer et al (53) provide broader perspectives. Even though many issues are interrelated, manpower planning, when viewed as a particular function in the personnel system, can be seen to be in the realm of strategic and tactical planning in contraposition to the more operational nature of personnel administration and management (158, 239). Geisler (73) discusses the difference at length and concludes:

> "The manpower planning staff deals with people quantitatively, not individually...An exception...occurs in the case of, critical skills allocation or corporate levies..."

Since men have worked in commercial groups for centuries it seems reasonable to question the sudden interest in manpower planning. Cassel (34) attributes it largely to a shortage of manpower in a technologically complex, rapidly evolving society. In the context of the British civil service, Smith (180) advocates efficiency through foresight. Wikstrom (227) identifies seven contributing factors:[5]

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[5] See also (204).

- rapidity of technological change (22),
- long lead time for training and development,
- tight labor market,
- demographic changes (e.g., lower birthrate during depression produced decrease in 35-44 age group),
- manpower coming to be viewed as critical corporate resource,
- government influence through programs and contracts,
- manpower planning is becoming accepted as integral part of corporate planning.

The last point only serves to attest to the complexity of manpower planning as an integral component of corporate planning - a vast and ill-defined field in its own right. As Lorange (118) comments in his survey:

> "I am left with the uncomfortable feeling that somehow it is difficult to fit the bits and pieces together. There seems to be considerable lack of consensus in the literature when it comes to such central issues as the nature of planning systems, what constitutes relevant empirical areas of research, etc. Also, the common vocabulary seems to be surprisingly small and too often lacks adequate definitions. The research design frequently seems to be sloppy, particularly in neglecting to state assumptions when limit the universality of the sample."

Geisler (73) cites manpower planning as an integral yet distinct aspect of corporate planning and Wikstrom (227) reports manpower methodologies in several large corporations. From the vantage point of Industrial Relations, the complexity can be summarized as consisting of

the goals, values, and power of a firm competitively interlocked with those of government, labor, and other private firms, all of which are subjected to external environmental pressures of the economic, political, legal, social, and ecological systems.

In an effort to abstract the complexities involved, various conceptual models have been advanced. Vetter (208) proposed the four phase model of fig. 2 consisting of strategic, tactical, operational and evaluation feedback steps. Walker (213) suggests a two-dimensional concept in which the forecasting, programming, and evaluation phases evolve through four stages of successive complexity culminating in the ultimate human resource system. Purkiss (181) presents a feedback flow model in Fig. 3 which is generally valid outside its original context in the UK steel industry. Picur's (157) model in Fig. 4 is an expansion of Cassel's (33) framework to include the housekeeping function as an integral component of a manpower information system. Patten (150) puts forth a more seminal model.

Even a cursory perusal through the literature will rapidly convince the novice that any aspirations regarding corporate manpower planning systems are largely predicated on the existence of computer-oriented firms with at least a manual personnel data system (58, 173). Indeed, the field can be viewed as embracing information systems, management participation, and mathematical modelling - largely represented by the disciplines of computer science, organization theory, behavioral science, and operations research. As it is the intent of this paper to restrict itself to a consideration of the latter only, only the briefest mention will be made of the other two aspects.

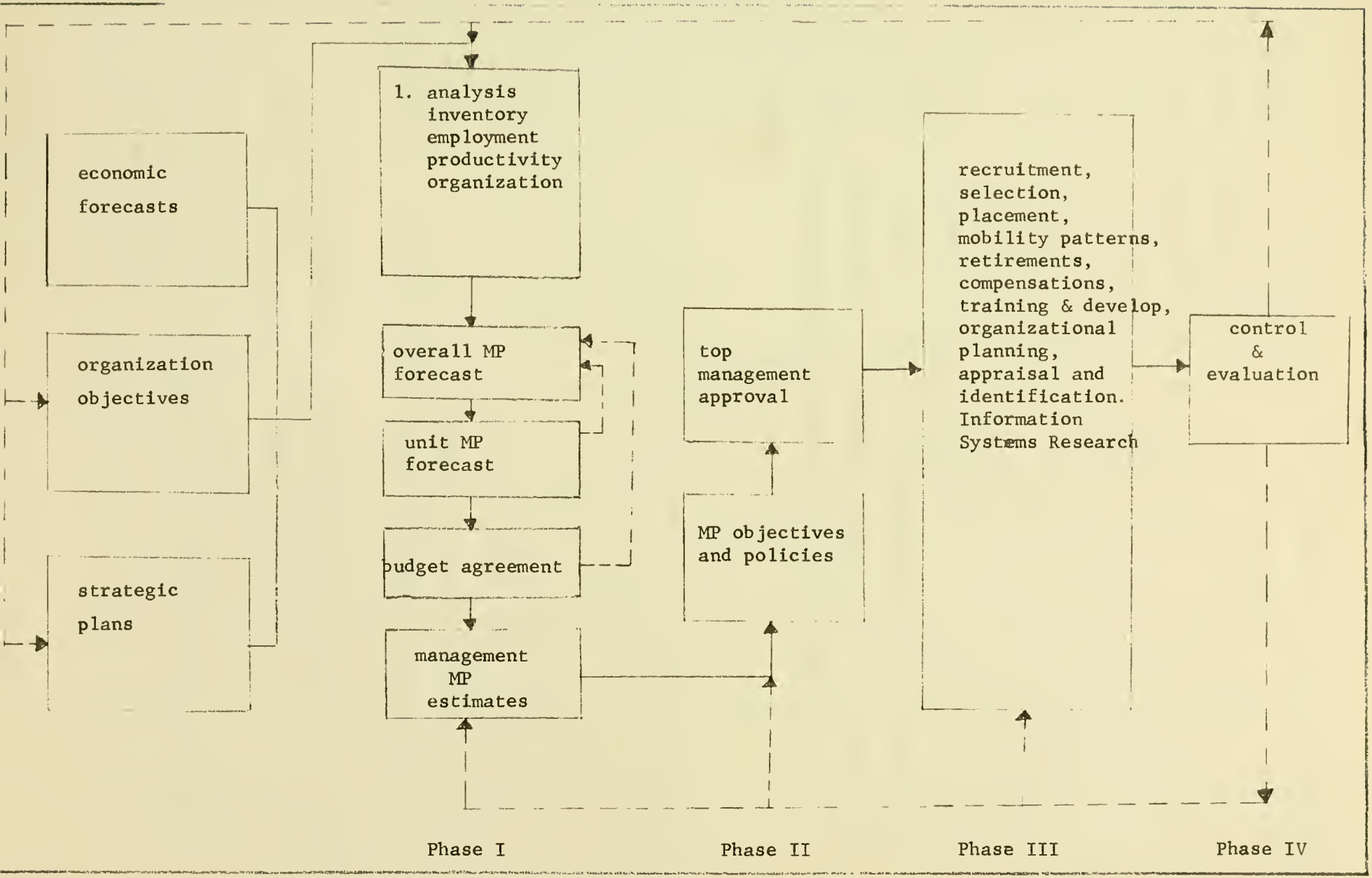

Figure 2: Vetter Model of Manpower Planning Phases
Source: Hollister R.L., "Modern Manpower Management - A Micro Approach", doctoral dissertation University of Utah, Business Administration, Dec., 1973.

Black (18), Morgan (137), and Weatherbee (215) cover basic EDP aspects. Carter (32) indicates the heavy commitments of the Armed Forces to EDP which, in point of fact, have the most extensive and sophisticated systems in existence (119, 144). Finally, the OECD has completed a study of personnel information systems in six European countries (8). A representative computerized personnel record is formulated in (228) and Ficarra (64) records issues in the design of data bases. Finally, Picur (157) provides a comprehensive treatment of a "core requirements" manpower information system shown in Fig. 4 and suggests the "Personnel Rapid Access Management Information System" as the most sophisticated one commercially available (156), although most corporations and government institutions currently prefer to develop their own.

On the management side, Mackenzie (120) reviews organization theories in bureaucracy and Likert indicates changing group relationships in organizations (116) while Wilson (230) specifically examines the relationship between organization theory and manpower planning. The tremendous influence of sociology and psychology (170) can be seen in almost any book on personnel administration (158, 239), particularly in the areas of personnel testing (4) and performance appraisal (27, 77).

At this point it might be appropriate to comment on the extent of manpower planning activities. Unfortunately, little work seems to have been done in this regard. In a survey of Minnesota firms with over 500 employees, Heneman and Seltzer (85) discovered the following among the 50 respondents:[6]

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[6] [illegible] of the Minnesota Survey

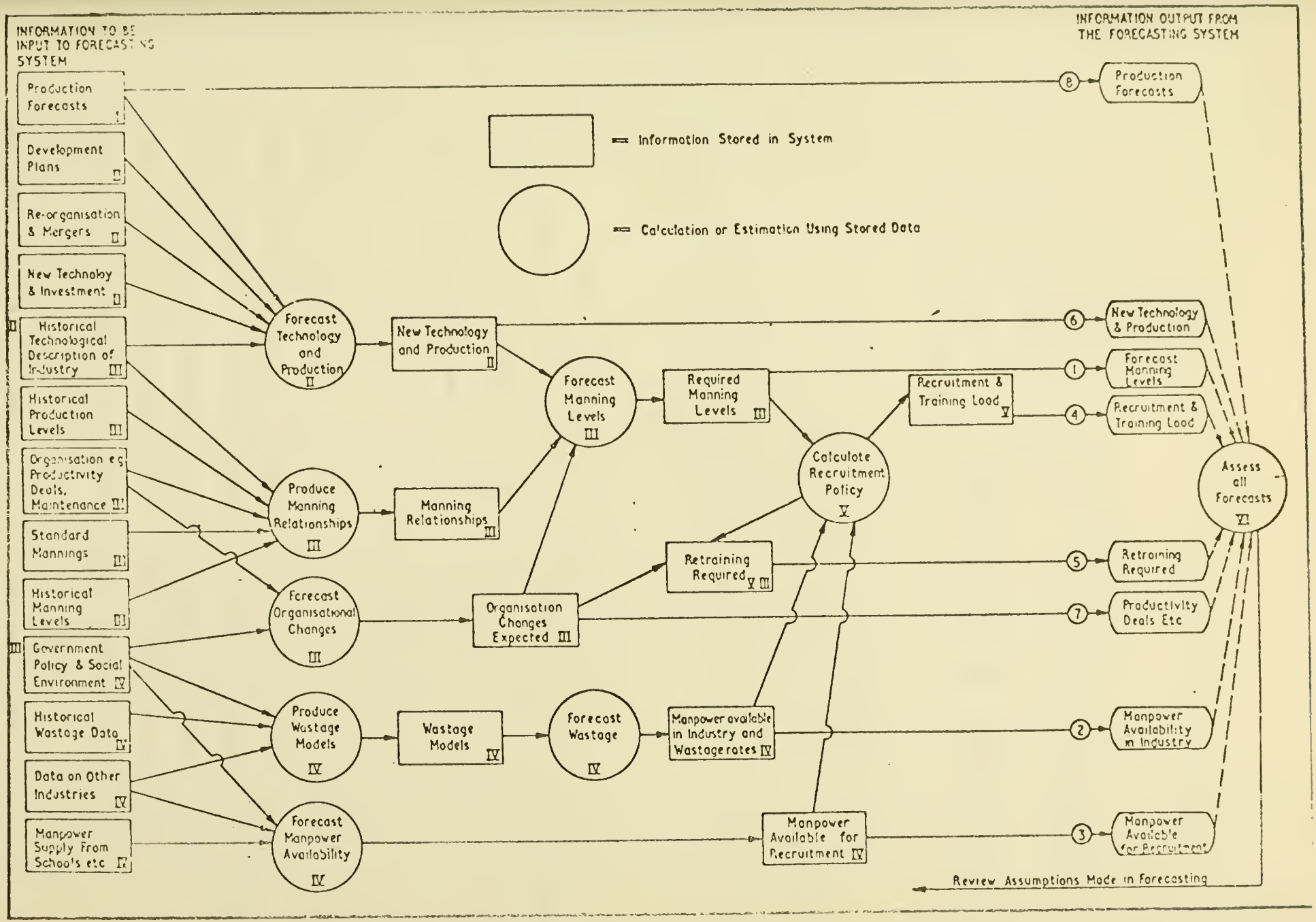

Fig. 3: Purkiss Model of Manpower Planning
Source: Purkiss, C.J., "Models for Examining and Optimizing Manpower Deployment; International Research Systems, Ltd. (Surrey, UK)

- 72% forecast all or some proportion of their manpower requirements;
- 36% forecast external manpower supply;
- 59% began their manpower forecasting activities within the previous five years;
- 71% prepare their manpower forecasts once each year, or at longer intervals.

A nationwide survey (125) of 775 local and state governments, federal agencies and private corporations, reported that one third of the respondents were using a computerized manpower information system, manpower projection methodology, or affirmative action programs with the work being admittedly limited in scope.

A review of manpower models presents authors with the dilemma of approaching issues either in their functional context (e.g., recruiting, training) or in the modelling methodology applied (e.g., renewal theory, linear programming). Whereas Niehaus (145) opted for the latter and Vajda (206) also used this approach in detailing a brief history of modelling, this paper will attempt to combine both points of view. Starting from the simplest but comprehensive static "flow" models concerned with recruitment, promotion and attrition within an organizational hierarchy, this survey expands to include the supporting function of needs analysis in corporate manpower planning, and moves on to look at more complex dynamic flow models. Generic assignment models are considered next, followed by an examination of other problems in the context of Picur's (157) manpower information system. Finally, trends and issues are briefly looked at prior to mentioning manpower planning summaries and bibliographies.

4.2 Static Flow Models

The "balance" or "accounting equations" represents the basic concept of manpower stocks and flows in simplest algebraic terms. As detailed by Walker (212) and Haire (79) the flow relationship may be stated by:

$$\begin{aligned}\text{manning strength}(t-1) = {} & \text{manning strength}(t) - \text{promotions in}(t) \\ & - \text{recruitment}(t) - \text{net transfers}(t) - \\ & \text{promotions out}(t) - \text{wastage}(t)\end{aligned}$$

Typically, a system of accounting equations representing several seniority levels within an occupational classification is solved for some unknown parameters such as promotion and recruitment flows.

Actuarial models are perhaps the earliest methods employed (172) and still find application today (92, 217). The fraction of surveying entrants represents a typical problem. Thus, given an average loss rate, w, the remaining portion of the original group after t years is $(1 - w)^t$. For small w, a considerable degree of computational complexity is bypassed by the exponential approximation e^{-wt}. Whereas actuarial models assume stationary populations and age distributions, renewal or replacement models (50) relax these constraints. Bartholomew (9) deals with various issues at length and is a classic reference for the field. Cotterill describes an application for the Canadian Armed Forces (49) while Robinson (163) deals with two-stage replacement strategies in the determination of the duration of stay in training grades prior to promotion.

Markov analysis has demonstrated itself as one of the most powerful tools for flow models and, indeed, for all tributary issues as evidenced by the legion of articles. Merck (132) and Vroom and MacCrimmon (209) deal with the basic concepts while Rowland and Sovereign (165) provide a basic demand-supply industrial problem.

As can be easily appreciated, the nature of flow models is such as to make it nearly impossible to isolate the interrelated phenomena of promotion, age distribution, recruitment and wastage. Forbes (68) deals with promotion and recruitment policies paramaterized on the expansion-contraction of an organization using Markov analysis. Butler (29) investigates a method for equalizing promotion rates between grades within similar hierarchies. Using the transition matrix Mapes (126) illustrates how the inverse, expressed as a fundamental matrix, directly yields mean age of promotion. Young (240) is also applicable to promotions. Young and Almond (242) examine the long-term implications of fixed recruitment and promotion policies. Keenay (95) uses renewal theory to identify and forecast promotion blockages based on age distributions.

The key to accurate manpower forecasting lies in accurate projections of unscheduled attrition. The study of labor turnover is complicated not only by the difficulty of defining the measurement variable (48, 185) (annual departure from grade, survivor fraction, half-life, completed length of service), but also by its distribution function (12). In 1954 Silcock (175) reviewed the findings to date in labor turnover analysis and suggested that turnover theory should be based on actuarial techniques rather than on negative exponential models proposed earlier. Lane and Andrew (99) developed a lognormal model in which the distribution of wastage was related to length of service and

proposed two methods of analysis: cohort analysis in which the wastage characteristics of an initial homogenous group are observed over longer periods of time; census analysis in which two sample points in time are used to determine the wastage rates. Subsequent investigation established this as a sound approach (43, 241, 242). Bartholomew (11) suggests the use of mixed exponentials as an aid to simplification while Forbes (69) concerns himself more with estimation errors. Poisson distributions are mentioned by Bartholomew and Butler (12). Young (240) and Bryant (25) provide concise summaries of work in this area.

Bartholomew reviewed the entire field of stochastic models at the NATO manpower conference in 1971 (13) while Smith related them to the UK Civil Service (180). The Institute of Manpower Studies in the UK seems to be a focal point for current work in the area (see 185). The mass of literature on flow models makes it exceedingly difficult to suggest particularly noteworthy or intriguing work. However, from a viewpoint of conceptual innovation or technical merit several authors deserve mention. Bartholomew (9), of course, stands as a central figures in the area. In the UK, Forbes provides both a comprehensive Markov model (68) and considers the question of goodness of fit (67) as do Mahoney and Milkovitch (121) in the USA in developing their stochastic model for internal labor markets. Young and Almond (242) introduce eigenvalues as an aid in analysis. White (224, 225) adopts a unique perspective by considering the flow of job vacancies rather than people in a labor market. Finally, Dill, Gaver and Weber (52) are cited for their development of stochastic models, discussion of simulation techniques, and suggestions for future endeavors.

4.3 Manpower Requirements Analysis

The static nature of the supply-oriented stochastic models assumes a prerequisite knowledge of manpower demand or requirements. However, very little work seems to have been done on the requirements forecasting side. Investigation is complicated to an extent by the interaction between demand and supply, in that abundant availability of a particular trade-profession will bias the demand planning towards it while a shortage will initiate substitution effects in the opposite direction. Wilson's article (231) underscores the interrelated nature of demand and supply in his consideration of technological, organizational and environmental factors affecting organizational structuring. Heneman and Seltzer (85, 86) rank order the ten factors commonly utilized in predicting requirements: sales, quality of internal labor, facilities expansion, workload (production), external labor supply, turnover, technical and administrative change, new products, company plans and objectives, budgets. Bell et al. (16) refer to four main techniques[7] of forecasting requirements: management intuition, statistical extrapolation (57), work study and productivity measures (53, 62). All four factors are included by Caputo (31) in the determination of US military pilots. In forecasting Civil Service needs Halpern (80) uses extrapolation and least squares estimates. Clark (43) rejects extrapolation and maintains that a combination of management estimates and productivity analysis hold the answer for planning the US Civil Service, Norden (146), on the other hand, advocates the life-cycle approach using Weibull Distributions

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[7] See Chapter 6 of (184) for an expansion of these techniques.

for estimating needs in well-structured projects. Milkovitch et al. (34) employ Delphi Procedures to obtain professional manpower forecasts and relate demand to sales and productivity indices as well as growth parameters. Doeringer et al. (53) report that Hartle (83) is critical of the use of individual employer forecasts. Bell et al. (16) recommend Ferber (63) and Wedderburn (220) for additional reading; Niehaus (145) cites Blanding et al. (19). Ref. 190 is an annotated bibliography of USAF requirements determination for specialty and general personnel. Aggregate manpower requirements[8] were investigated by Holt et al. (88) as part of production scheduling for a paint company. Their linear decision rule considered manpower requirements as a function of current work force, order backlog and inventory level[9]. Hanssman and Hess (81) simplified the model as a linear programming approximation and Goodman reformulated it in goal programming terms (76). El Agizy (60) extends this work by allowing for interaction among skill categories as well as workload uncertainty by skill. As might be expected, requirements forecasting methodology at the corporate, regional and national level is highly correlated.

4.4 Dynamic Flow Models

In recent years the steady state stochastic flow models have been supplanted with dynamic formulations based on mathematical programming techniques with multi-attributed and multiple horizon objective functions to regulate the trade-offs among promotion, recruitment and organizational expansion and size. As opposed to static models, these models are characterized by a greater appreciation of both the multi-dimensional aspects of planning that produce a viable policy

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[8] See (26,128) for a detailed analysis and review.

[9] See also Doeringer et al. (53) for a single equation requirements model.

(recruitment, promotion, transfers, training, attrition, career ladders) as well as the data processing requirements to support it in practice. Quite often the models are intended to assess or simulate various corporate policies.

Purkiss (161) developed a linear programming (LP) model for hiring, firing, and redeployment of workers in the British Steel Industry (see Fig. 4). Assuming constant flow rates, his model minimized manning costs (overmanning, undermanning, and current level). Purkiss acknowledged the difficulty of determining cost coefficients and agreed that it is preferable to have hierarchically structured sub-objectives. Morgan (138) proposes an LP model for the Royal Air Force in which he minimizes costs associated with recruitment (advertizing and training), redundancy, overmanning, and pensions by controlling manning levels, promotions and redundancies subject to establishment and flow constraints. Gear et al. (72) present a resource allocation model in a R&D multi-project environment.

Although it is a powerful tool, the unidimensionality of the objective function and the minimization/maximization of costs directly associated with the control variables make LP somewhat awkward to use. This was pointed out by Lee and Jaaskelainen (106) who advocated the use of goal programming (GP) after an assessment of production planning methodologies.

Discovered by Charnes and Cooper in 1961 (35) GP[10] remained dormant until only a few years ago when it started coming into its own (105). Whereas LP attempts to optimize the weighted sum of variables, GP minimizes the weighted sum of deviations from specified targets or goals. The goal-oriented or normative nature of the solution technique (which can be solved using standard LP software packages) leads to a 'satisficing' (176) solution of a hierarchically ordered multi-attributed objective function. Patz (151, 152) describes a steady state model with explicitly stated promotion and attrition rates which minimizes the weighted sum of discrepancies in the desired establishment at each grade level as a means of studying recruitment, retention, manning surplus and shortage. Clough et al. (45) propose four related GP models to plan pilot training and mission effectiveness in the Canadian Armed Forces. Price and Piskor (160) give a working application for controlling the structure of the officer corps of the Canadian Armed Forces (CAF) using a commercially available LP package. Implicitly expressing budgetary limitations in terms of grade promotion flows and establishment levels, and bounding the promotion and manning values at each of the 4 tiers in the 31 classifications, they minimize the weighted sum of deviations from promotion and manning goals in a hierarchical multidimensional objective function expressing budgetary constraints, rank seniority and classification preference, overmanning and undermanning, overpromotion and underpromotion. In operation, since November 1971, the system is being actively used both for manpower and organization control as well

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[10] See Ijiri (89) for a technical treatment and (105) for current uses.

as for policy evaluation. In a series of papers summarized in (39) Charnes, Cooper and Niehaus document a similar approach to the US Navy civilian manpower system (OCMM). Whereas the CAF model requires explicit statements of attrition and implicitly accommodates budgetary limitations, the OCMM model contains an imbedded Markov process to account for transitions and accommodates explicit statements of financial constraints. Because of the extensiveness of the models, the magnitude of the data management problem, and the implication for organizational theory in adapting to a man-machine symbiotic planning environment, the OCMM effort might turn out to be the prototype experience in large scale computer-assisted integrated manpower planning. Indeed, the combination of simulation, Markov analysis, and GP used by AT&T in an integrated software package (98) suggests that we may already be there.

While it might seem to the uninitiated reader the LP models currently dominate the field, this is not necessarily the case. In many instances, aggregated simulation models precede more complex work. Another approach is "entity" simulation modelling in which individual records are stochastically "aged" during a simulated time horizon. PERSYM (78) is one such system reported in use by the US Defense Department and Wishhart and Ko (233) register a similar intent on a smaller scale for the British Civil Service.

4.5 Assignment Models

A critical issue in manpower planning is the efficient utilization of human resources through proper matching of people with jobs. Thorndike (193) was one of the first to give formal recognition to the system aspects by identifying three types of placement decisions: selection, classification, and classification-selection. In operations research literature this whole class of issues is simply termed "transportation" and "assignment" problems (210) whose specific structure has been exploited through the development of fast algorithms. The assignment problem is applicable in two similar situations:

> classification assignment - individuals are optimally placed in occupational categories best suited to thier skill aptitudes.
>
> personnel allocation (posting) - individuals are optimally moved to vacant positions within their occupational category.

The two problems differ largely in the optimizing criteria. For the one-time classification assignment the skill aptitudes of hirees (recruits) are matched against desired classification aptitudes; the allocation problem typically minimizes dollar costs although other variables are also included. Leiman (111) presents an expository article which focuses in on the mechanics involved. Conceptually, a "man" matrix containing a row for each individual will record characteristic variables as columnar data. Similarly, a "job" matrix (or classification) will list the required characteristics in successive rows

for the jobs (classifications) expressed with column indices. The product of these two matrices will result in "value" or "worth" criteria for each man/job (classification) combination which are then maximized or minimized - depending on the nature and particular problem formulation.

Hatch (84) reports on personnel classification systems for the US Navy, Army, and Marine Corps based on several criteria: maximization of occupational preferences of recruits; minimization of travel costs associated with relocation; maximization of assignments meeting desirable prerequisites; maximizing probability of success in assignments. Ewashko et al. (61) report on the proposed approach in the CAF. Stolley (186) describes the approach used in the German Armed Forces.

From a posting perspective, Ewashko et al. (61) use predicted moving costs, posting preferences, language (French/English) requirements as criteria in the CAF. Drake et al. (55) document a smaller application in the British Civil Service while Mensch (131) considers modification of the assignment problem to a stochastic problem by considering the cost coefficients of the objective function to be normally distributed.

OCMM experiments with GP static allocation models using aptitude tests, supervisory evaluation, and task analysis are reported in (101) and (136). Steuer and Wallace (187) report on a GP selection and placement model using grade point coverage, years of experience, and aptitude test scores as predictor attributes. Moreover, Charnes[11]

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[11] See (36) for a selective review of assignment models.

et al. (41) have pointed out the need for dynamic allocation models that take into account possible future job sequences and the influence of previous experience on future career possibilities. In his Ph.D. dissertation Henschke (87) reviews classification theory, considers both static and dynamic assignment models, and formulates a total systems approach dealing with recruitment, training and assignment problems.

A discussion of the behavioral aspects of assignment has been purposely avoided as it constitutes a field in itself. (56) is suggested as an applicable review paper.

4.6 Manpower Information System

Although flow and assignment models may be readily discussed within the content of well-defined areas in management science, the truly interdisciplinary nature of manpower planning demands that remaining topics be considered within a broader conceptual framework. Because of his system analytic perspective of the personnel function as a group of subsystems with interconnecting information flows, Picur's (157) model of the manpower information system has been selected as the vehicle for further discussion of the topic. Fig. 4 is an extremely abbreviated abstraction of his work. The round brackets in Fig. 4 indicate additional bibliographic material to augment Picur's own extensive review.

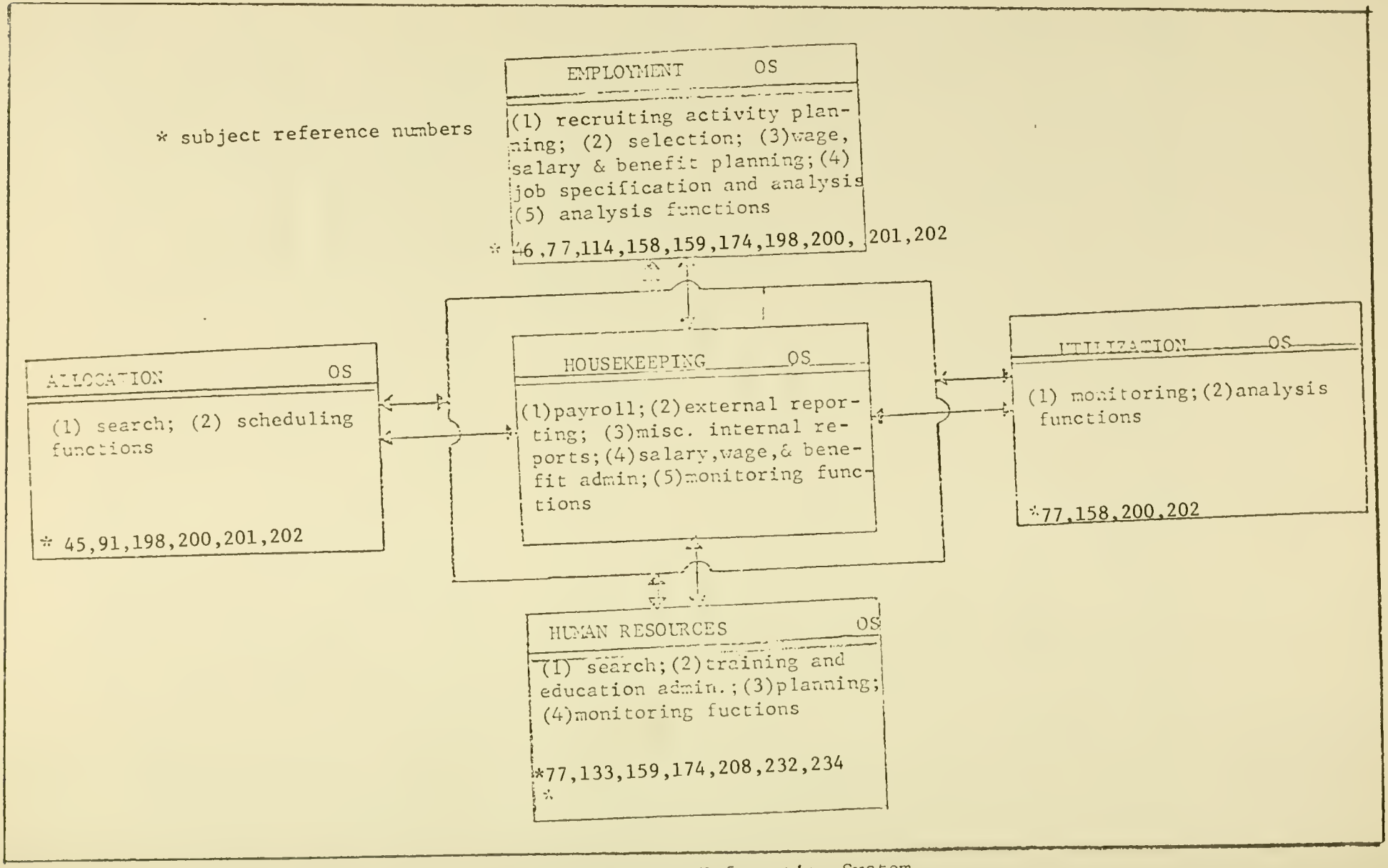

Fig.4: Picur Manpower Information System

Abstracted from Picur R.D. A Framework For a Manpower Information System. Doctoral Dissertation, Northwestern University, August 1973

Picur builds on Cassell's earlier work (33) to develop a model containing five sectors or "operating systems (OS)": housekeeping, employment, human resource, allocation and utilization. As the name implies, the housekeeping OS acts as a centralized data channel to collect, sort, analyze, store, update, and retrieve basic administrative data such as: payroll (regular, vacation, bonus, and incentive); administration of wages, salaries and benefits; telephone directories and mailing lists; external reports (tax, employee contributions, equal opportunity, union reporting, employee benefits, and salary surveys).

The allocation OS deals with the effective placement of individuals within an organization. The search function identifies the man, based on his skill inventory, identifies the position using task analysis, and identifies a potential back-up. The scheduling function dealing with personnel allocation has been discussed under assignment models. Aggregate manpower scheduling is covered in (17, 76, 81, 88). Productivity maximization through efficient shift scheduling is investigated by Bodin (20) who reviews the work of: Bennet and Potts for the Adelaide, Australia bus system; Altman et al., Bodin et al., for the sanitation department of New York City; Heller for the St. Louis Police department; and Monroe for airport baggage handlers. Picur classifies the promotion sub-system as an integral part of the allocation OS. The quantitative aspects of promotion were covered under flow modelling (29, 39, 68, 126, 160, 225). From a behavioral aspect Basset (14) pinpoints four promotion strategies:

- results oriented;
- status-quo orientation - "who best fits in";
- ability orientation - assessment of potential through tests;
- "don't make waves" orientation - stresses avoidance of past mistakes.

References (200) and (202) provide bibliographic references to other qualitative considerations. Of particular interest in the allocation process are the skill inventories which, using Leiman's (111) terminology, often form the basis for the "man" matrix. Kaumeyer (93) gives a picture of the automatic skills retrieval system for one aerospace firm, while Murphy (141), portrays a very comprehensive system for another.

The Employment OS contains five functions: selection; wage, salary, and benefit planning; job specification and analysis, recruiting activity planning, and analysis. The analysis function deals with turnover (43, 99, 175, 179, 184, 185, 240) severance costs, pre-employment testing and validation (4), employment agency effectiveness, selection criteria development, media effectiveness analysis. Recruiting/selection aspects have been discussed under assignment models. Sands (168, 169) presents a costing model for US Navy enlistment that allows for determination of the optimal selection ratio. Lilien and Rao (117) suggest an integer LP hiring model based on expected employee performance, categories of hiring sources and subjective employee-value functions using length of service in job, learning curves, employee cost and worth. Niehaus

et al. (143) give an example of interactive determination of hiring using a GP model. References (51, 77, 96) deal with computer-assisted selection while (159, 198, 200) provide bibliographic references. Job specification and analysis is closely related to skills inventories. The former attributes task requirements to a job whereas the latter records the task availabilities of an individual. The US Manpower Administration has prepared a descriptive and comparative review of research and development of Job Analysis (205). Historically, job descriptions have been based on the subjective assessments of job analysts. The development of functional job analysis (65) based on task structures describing how cognitive resources are directed at data, interpersonal skills at people, and physical resources at things offers a controlled language format for capturing job content in a standardized fashion. In recent years the USAF has been sponsoring a program of quantifiable task analysis. Christal (42) presents an overview of the purpose, applications and progress of computerized task analysis embodied in the CODAP (Computerized Occupational Data Analysis Program) software. Bottenberg (21) provides a more detailed view of the operation of the system explaining how overlaps between jobs are determined using task inventory responses from the surveyed individual. The overlap criteria is then used to cluster jobs into job or career hierarchies using CODAP. Archer (6) illustrates with mathematical examples. The Chase Manhattan BAnk (164) has developed a similar computer-based occupational data retrieval system. Bibliographic references are available in (201) and (42).

As defined by Picur (157) the utilization OS is concerned with means of motivating and encouraging high performance. He goes on to say that current interest largely centers on performance evaluation and summarizes the majority of techniques used from Doiron (54): adjectival rating scale; method of pair comparisons, graphic rating scale, critical incident method, forced distribution method, man-to-man, free form evaluation. Cangemi (30) cites several sources of error in personnel evaluation: personal bias; central tendency - rater fails to adequately discriminate levels of performance; halo effect - strong personal bias towards individual results in similar ratings on all characteristics; logical error. As a step towards decreasing these errors, Colvin (47) suggests scaling the assessment by dividing the assessment value by the group average. Weinberger (222) has implemented a software system based on analysis of variance which monitors statistically significant deviations in performance ratings in the CAF by classification and by geographic location. Using correlational and multiple regression analysis Paul (153) found predictive power in age, education and experience as measures of performance.

Human resource accounting (66), human capital budgeting (191, 236), and cost-benefit analysis is the most intangible area of manpower planning primarily because there exists little consensus on "what" and "how" to measure variables. From the early work of Brummet et al. (23), Lev and Schwartz (113) extend HRA to corporate financial statements and Saden and Auerbach (166) pose a stochastic model for valuation. In describing the human resource planning process Walker (213) identifies three primary approaches for estimating human resource value:

- "Accrued costs: An accounting approach based on historical asset-costs/predicted-values, i.e., an organizational systems approach that examines human facts in relation to organizational performance.
- Replacement value: a "market value" approach pioneered by the insurance industry in the 1950s and 1960s.
- Economic Value: a discounted present-value approach based on projecting earnings of the individuals and/or other pertinent variables."

He goes on to state that human resource planning is an evolutionary process that should be geared to its requirements and capabilities. Picur takes a more concrete stance by selecting specific items of consideration. The search function encompasses the identification of management talent, (3) perceived corporate needs, and distribution of talent. A comprehensive survey of educational and training practices is offered in (133) and Leese (107) is suggested as an interesting approach to the scheduling of training. Patten (150) gives broad coverage to the issue while Greenlaw and Smith (77) focus on management games, computer-assisted instruction and the use of PERT in programmed instruction. Lilien and Rao (117) record preliminary conclusions on a cost-benefit model for recruitment with both stationary and quasi-stationary promotion and attrition values.

4.7 Trends and Issues

In projecting future trends in manpower information systems, Picur (157) states that it is becoming generally accepted that manpower planning and programming aspects consist of a two stage process in which long-term requirements are forecast and reconciled with the short-term supply (212, 227). Moreover, he foresees the integration (53) of manpower information systems (strategic, tactical, and operational planning) with other corporate functions (materials, finance, capital budgeting). Indeed, it would seem that the OCMM effort to develop prototype dynamic multi-level mixed (civilian/military) manpower systems is approaching this threshold (39, 40, 75, 144). Reference (37) and (38) in particular summarize the continuing saga to utilize GP methodology with embedded Markov Chains and associated I/O models for strategic total force planning along with satellite sub-models of similar structure for tactical decisions[12]. While the computer problems and operations research methodology seem to have been suitably addressed, it is the third main discipline of manpower planning - behavioral science and organization theory, that could be the deciding factor in this multi-level approach that involves numerous participating decision-making units.

Although the behavioural aspects have not been stressed in this bibliographic survey, several authors have reported work in this area. Anderson and Emmerichs (5) use the System Dynamics (70) methodology

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[12] Although the work is not as well documented, it seems plausible to assume that the other Armed Services are comparably advanced.

to model aggregate behavioural interractions among acquisition, maintenance and retirement policies as a result of policy cuts in military retirement pay. Weber (219) utilizes simulation to study the interrelationships between individual behaviour, personnel policy decisions, the labor market and organizational environment. Miller and Haire (135) offer a model to study small group dynamics in a working environment subject to personnel policies, career opportunities, compensation schemes, and authority relationships among others.

Although manpower planning has rapidly evolved into a maturing discipline, it must continue to do so at an even greater pace it it is to tackle the emerging issues confronting it. Burack and Walker (27) dwell on the impact of new technologies, community and business responsibilities, international operations, obsolescence and retraining, employment opportunities for minorities and disadvantaged, and the emancipation of women. The anticipated changes in the industrial relations scene are covered by Somers (183). Furthermore, the computer revolution will continue to affect manpower planning through its new implication for management (142), the growing number of databanks (223), and the impact on individual rights to privacy (203). Finally, the introduction of new harware technology along with distributed real-time capabilities in an increasing "wired city" environment will simplify data assimilation on the one hand, but at the same time, may threaten the entire sociological and psychological underpinnings of manpower planning as it exists today.

While the recent explosive interest in manpower planning literature would seem to suggest that its use is widespread, quite the contrary is true. For the most part corporate manpower planning is restricted to military and government agencies with some participation by larger corporations. If the experience in the Canadian private sector cited by Bennet (17) is to be used as a yardstick of performance, a high degree of cynicism and disappointment may well be warranted:

> "But despite its rapid development, and wide acceptance, the verdict must be that...it has been remarkably ineffective... The Economic Council of Canada recently released a survey that in effect says that most Canadian businesses have failed to build even the fundamental elements of a workable manpower planning process. In addition, from our experience as consultants to large firms, we can verify that manpower planning has generated much activity but few lating results."

He goes on to attribute three predominant causes for the state of affairs:

> "Manpower planning has been wrongly thought to be an exercise in precision, contingent on the details of the long-term business plans.
>
> Management development has become a separate activity, whereas it should be an integral part of manpower planning.
>
> Planners ignore the basic criteria for successful implementation (internal public relations, strong senior management commitment, capable manpower planners, emphasis on demonstrating effectiveness in the short-term as a prerequisite for continued and sustained long-term evolution)."

Bennet concludes his sobering article with a somewhat jarring truism - little hope can be held out for ameliorating the situation until the business community itself is motivated to reassess the situation.

5.0 SUMMARY

This paper represents an attempt to compile a bibliographic survey of the vast literature on manpower modelling particularly at the corporate level, and, as such, may be augmented by previous bibliographic reviews in the US (39, 94, 174, 177, 182, 197, 200, 201, 202), UK (102, 114, 154), and Canada (229). Reference 102 in particular organizes its review along functional technique categories with a brief annotated explanation of each. Moreover, the U.S. Civil Service Commission publishes a monthly review of personnel literature (199) and quarterly personnel management abstracts are available from the University of Michigan (155).

References 24, 124, 204 are recommended as a qualitative primer for the uninitiated in the field. Burack and Walker (27) and Greenlaw and Smith (77) provide a comprehensive non-technological treatment. The annotated bibliographic review by Lewis (114) coupled with the moderately technical coverage by Stainer (184) or Smith (181) are offered as a promising combination; or, alternatively, the narrower scope of 48 may be used with brief case studies (221) of manpower planning in changing technologies. The mathematically sophisticated reader will want to consider the NATO Science Committee series (45, 91, 179, 232) as well as (9) and books referenced by (7, 67). Ref. 178 offers a state-of-the-art view of operational manpower planning in the British Civil Service. Finally, a solid understanding of the OCMM (Office of Civilian Manpower Management, U.S. Navy) work is available in 37, 38, 39 .

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